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IONIZING RADIATION SURVEY

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Technical Note

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PHILLIPS LABORATORY
Directorate of Advanced Weapons and Survivability
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Many of the High Power Microwave sources currently use relativistic electron beams (REB). Typically, the total energy contained in the REB is not converted into microwave energy. This remaining energy will produce an ionizing radiation hazard within our laboratories. This report provides a reference for the calculations and considerations that must be accounted for in the setup for a new experiment. This manuscript will not be exhaustive in detail; however, it is a good reference for new people in our laboratory.

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INTRODUCTION

The microwave sources studied by the High Power Microwave (HPM) Group are typically driven by relativistic electron beams (REB). These REBs typically are not fully converted into microwave energy. The energy remaining in the REB is converted into ionizing radiation when the beam hits a wall. The material with which the wall is made, the placement of shield walls and other equipment, and the distance between the REB target and laboratory personnel determine the ionizing radiation hazard within our laboratories.

This report will provide currently used techniques to determine hazard areas, and the documentation required by the Ionizing Radiation Safety Board to begin a new research project. A majority of the research staff at the Phillips Laboratory will be familiar with the material presented in this report. However, most newcomers will not be aware of ionizing radiation and how to determine if an area is safe.

Additionally, this report will provide a comprehensive document (as of its date of preparation) on the capabilities and ionizing radiation hazard within our experimental area. The calculation to be presented in this paper will demonstrate the methodology and comparison between an actual survey conducted during December 1990 and January 1991. The reader should notice that typically the calculations overestimate the measured X-ray hazard by at least a factor of 2. This is as it should be because we are dealing with the safety of our people.

The primary references for determining the radiation dose and wall attenuation are <u>NRL Plasma Formulary</u> (Ref. 1) and <u>Medical X-ray and γ-ray Protection for Energies up to 10 MeV</u> (Ref. 2). These two references are not the only ones available, however, they have been found to be complete and give satisfactory results for comparison between calculation and measurement.

CALCULATIONS

To begin the process, one needs to know the capabilities of the various electron beams devices and the wall material of the beam dump. Typical materials are aluminum (Z = 13) or stainless steel (Z = 26). Currently the walls or surfaces on which the beam deposits its energy are typically grounded. However, the microwave sources may have "depressed collectors." The use of a depressed collector would reduce the energy of the electron beam and the resulting X-ray dose. Table 1 shows the electron beam accelerator parameters currently used in studies of HPM sources:

Table 1. Electron beam accelerator parameters.

	Beam Voltage (MV)	Beam Current (Amperes)	Beam Pulse Length (μsec)	# Shots/Day	Wall Atten.	Atomic #
RAMBO	0.360	25,000	1.0	40	1.7E-6	26
CRONOS	1.0	10,000	1.0	40	7.3E-5	26
IMP	0.4	4,000	0.3	40	1.7E-6	13
SNAP	0.15	75,000	1.0	40	4.6E-9	13
HTD	0.15	3,000	1.0	40	4.6E-9	13
TDX	0.15	3,000	1.0	1,000	4.6E-9	13
CDS	0.15	3,000	1.0	40	4.6E-9	13

The data from Table 1 are used in determining the total radiation dose at 1 m from the beam dump. The equation from Reference 1 is:

$$D(rads) = 150\ V^{2.8}\ Q\ \sqrt{Z} \tag{1}$$

where V is in MV, Q is in coulombs, and Z is atomic number of the wall material. The total charge deposited $Q = I * \tau$, notice that we have assumed a square shape for the electron beam pulse. This assumption is typically not valid, and as such we overestimate the total dose produced. The results of Equation 1 for the total estimated dose at 1 m for the seven machines are listed in Table 2.

Table 2. X-ray dose at 1 m.

	rads/shot	rads/day
RAMBO	1.094	43.775
CRONOS	7.65	306.
IMP	0.05	1.996
SNAP	0.2	8.003
HTD	0.008	0.32
TDX	0.008	8.003
CDS	0.008	0.32

At this point the investigator must decide if the calculated results are consistent, for both a dose per shot and total dose per day. The exposure standard for total dose is 5 rad/year, 1.25 rad/quarter. We want to stay below 0.125 rad/quarter, about 0.001 rad/day. If the total daily dose exceeds the standard, one

then needs to provide shielding around the REB. Typical shielding materials are high density concrete or lead. The amount of shielding is determined by how much you must reduce or attenuate the potential X-ray hazard. The shielding thicknesses may be determined from the data in Reference 2. From the graphs of attenuation versus wall thickness you find the range at which the radiation dose drops by an order of magnitude. For the case of a 2-ft-thick wall of concrete, one finds the values listed in Table 1. Additional attenuation is obtained by distance. The total dose calculated by Equation 1 may be scaled by r^{-2} for the typical distance (in meters) between the REB and where people stand (typically the control console).

RADIATION DOSE SURVEY

As soon as a new experiment is operational, that is, reliable, a radiation dose survey must be completed. A survey is done to verify that appropriate safeguards are in place. A floor plan of the laboratory floor space is recommended to ensure that all potentially hazardous areas are checked. The survey is coordinated with the Ionizing Radiation Safety Office. This office is a part of the base hospital and is currently responsible for the verification process.

Due to the current military restructuring, this office may not be available to complete a survey for you. However, you may arrange to borrow the required equipment to complete the survey yourself.

A diagram of the Building 322 laboratory bay is shown in Figure 1. The survey covered the microwave sources on IMP, TDX, and CDS. CRONOS had previously been surveyed while using a single source and is currently being upgraded to using four sources. RAMBO is not presently operational. The sources on

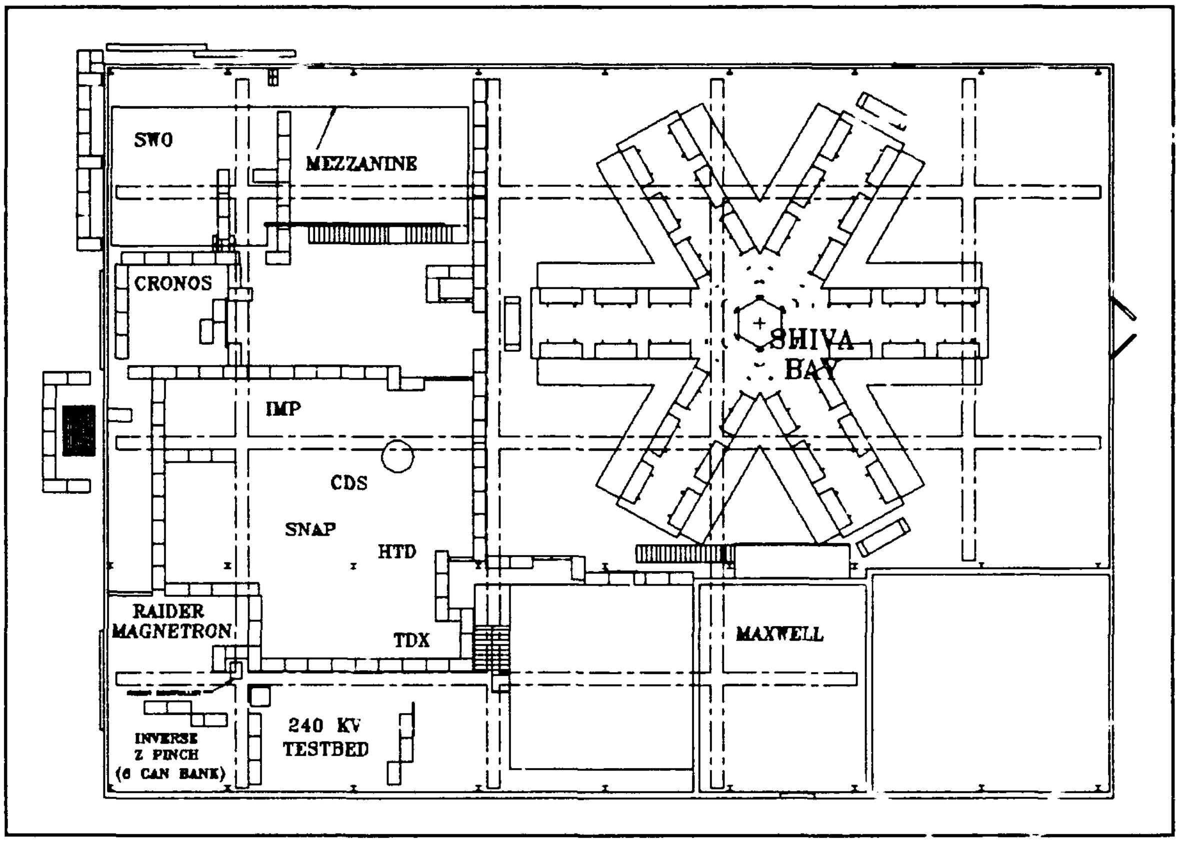

Figure 1. Building 322 laboratory.

SNAP and HTD are the same as on TDX and CDS. SNAP simply has multiple tubes. The survey results are listed in Table 3.

The data are averaged for a series of pulses (typically 10 or 20) of identical parameters as listed in Table 1. You should notice that all the measured dose levels are less than the computed values. These data may be used to verify that laboratory personnel are not in danger of accidental exposure, given the layout of the laboratory space. The data recorded at the pulser control console showed that typical levels are below 10 μrad/shot, this is consistent with the typical natural radiation level.

Table 3. Radiation survey results.

	rads/shot (cal. @ 1m)	rads/shot (meas. @ 1m)
RAMBO	1.094	****
CRONOS	5.408	****
IMP	0.05	0.005
SNAP	0.2	****
HTD	0.008	****
TDX	0.008	0.002
CDS	0.008	0.003

APPROVAL BY RADIATION HEALTH

The above results must be presented to the Radiation Health Panel to obtain permission to begin full operation. Due to the timing of their quarterly meetings, one may obtain conditional permission to operate from the Radiation Health Office if a survey is completed prior to a meeting. Also, if the pulser is not ready, but the calculations have been completed, one may obtain permission to operate until a survey can be completed. The Radiation Health Office is then allowed to give final permission following completion of a successful survey.

REFERENCES

1. **Book, D. L., <u>NRL Plasma Formulary</u>, Naval Research Laboratory, Washington, DC, 1987.**

2. **<u>Medical X-Ray and Gamma-Ray Protection for Energies up to 10 MeV</u>, NCRP Report #34, National Council on Radiation Protection and Measurements, March 1970.**